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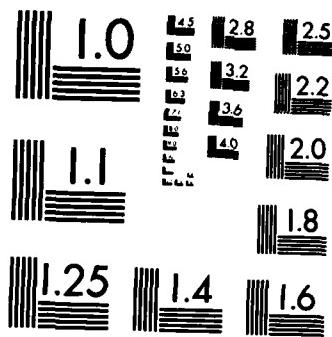
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Terrain and weather affect combat operations more significantly than any other physical factors on the battlefield. Historically, field commanders have not had the capability to fully exploit battlefield environmental effects for tactical advantage. The Corps of Engineers has initiated the ABLE program to develop and evaluate Tactical Decision Aid (TDA) software and products. The TDA's when implemented on developmental systems, will provide the Army with an operational capability to assess and exploit battlefield environmental effects as a force multiplier in combat operations. A Government-developed Geographic Information System (GIS) will provide the databases that the TDA software will access to generate products. A development strategy has been devised that involves assembling an ALBE Testbed, installing the GIS and TDA software, conducting field demonstrations and evaluations, and transferring the TDA software to various target systems currently in the life cycle development process. This innovative approach will facilitate fielding of ALBE software and products, and will provide battlefield commanders and their staff with the ability to better exploit the combined effects of terrain and environment in the decision-

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**AIRLAND BATTLEFIELD ENVIRONMENT (ALBE)
TACTICAL DECISION AID (TDA)
DEMONSTRATION PROGRAM**

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ABSTRACT

Terrain and weather affect combat operations more significantly than any other physical factors on the battlefield. Historically, field commanders have not had the capability to fully exploit battlefield environmental effects for tactical advantage. The Corps of Engineers has initiated the ALBE program to develop and evaluate Tactical Decision Aid (TDA) software and products. The TDA's, when implemented on developmental systems, will provide the Army with an operational capability to assess and exploit battlefield environmental effects as a force multiplier in combat operations. A government-developed Geographic Information System (GIS) will provide the databases that the TDA software will access to generate products. A development strategy has been devised that involves assembling an ALBE Testbed, installing the GIS and TDA software, conducting field demonstrations and evaluations, and transferring the TDA software to various target systems currently in the life cycle development process. This innovative approach will facilitate fielding of ALBE software and products, and will provide battlefield commanders and their staff with the ability to better exploit the combined effects of terrain and environment in the decision-making process.



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INTRODUCTION

Terrain and weather environmental effects are arguably the most significant and limiting factors for a commander in combat operations. However, collection of this data is a slow process, and in most cases environmental intelligence products cannot be generated with the speed needed to support continuous operations. Therefore, tactical decisions have to be made with limited knowledge of the battlefield environment, even though such factors can be detrimental to the performance of today's high technology Army systems. In addressing this problem, the Army is initiating development and fielding of advanced technology systems such as the All Source Analysis System (ASAS), Maneuver Control System (MCS), Digital Topographic Support System (DTSS) and Integrated Meteorological System (IMETS). These systems will provide the capability to acquire and process intelligence, maneuver, terrain and environmental information, respectively, in an efficient and timely manner. In addition, the Corps of Engineers, tasked with providing a synergistic approach to the efficient assessment and exploitation of environmental battlefield effects, has instituted the AirLand Battlefield Environment (ALBE) initiative.

ALBE will facilitate the acquisition, integration, assessment and exploitation of terrain, weather and other environmental information through a government-owned Geographic Information System (GIS). The GIS will provide for the implementation of Tactical Decision Aids (TDA's). Two major goals of the ALBE initiative are:

Provide Army material acquisition, training and doctrine activities with the capability of assessing and exploiting realistic battlefield environmental effects.

Provide the Army in the field with the capability to assess and exploit battlefield environmental effects for tactical advantage.

This paper will address the ALBE TDA Technology Demonstration program, one of the Army's top twenty technology demonstrations, and the GIS which provides the environment for generating these TDA products. This program is designed to provide a mechanism

for demonstrating and evaluating TDA products developed under the Corps of Engineers' tech-base efforts and to facilitate transfer of these products to Field Army systems. The TDA Technology Demonstration program will address goal two of the ALBE initiative. The primary objectives of the program are:

Develop and refine GIS software to support TDA product generation.

Develop and refine TDA software and develop the methodology to provide TDA software and products to Army operational units.

Demonstrate the use of advanced sensor systems for collection of near-real-time battlefield environmental data and use of the data in the generation of TDA products.

Obtain the test data necessary to support integration of ALBE TDA software and products on soon-to-be fielded Army systems.

The development strategy for the TDA Technology Demonstration program is to assemble an ALBE Testbed (ATB, which will be used as the vehicle for conducting the ALBE Demonstrations, implement and integrate the TDA software into the ATB, conduct a series of demonstrations and evaluations to gather data and develop methodologies for transitioning the TDA products to Army fielded systems, and transfer of the TDA software to materiel developers of the Army fielded systems.

BACKGROUND

The ALBE TDA Technology Demonstration program is being conducted under the auspices of the Corps of Engineers Directorate of Research and Development with the work being performed cooperatively by Corps of Engineers (USACE) and Army Materiel Command (AMC) laboratories. Participating laboratories include the Corps of Engineers'; Cold Regions Research and Engineering Laboratory (CRREL), the Construction Engineering Research Laboratory (CERL), the Waterways Experiment Station (WES), and the Engineer Topographic Laboratories; along with AMC's Atmospheric Sciences Laboratory (ASL). The TRADOC proponent for the ALBE Technology Demonstration program is the U.S. Army Intelligence School (UASICs). The Army Development and Employment Agency (ADEA) will support the ALBE effort by: facilitating the coordination necessary to execute the field demonstrations and evaluations with the appropriate FORSCOM and TRADOC element, and assisting in the integration of ALBE software and products into the Army's SIGMA C I architecture. The U.S. Army 9th Infantry Division will also support the TDA Technology Demonstration program by providing troops to operate and evaluate the ALBE software during Command Post Exercises and Field Training Exercises.

ALBE Testbed (ATS)

The ATB is designed for maximum flexibility (both hardware and software) to satisfy TDA developer requirements and provide a suitable demonstration vehicle which can function in a realistic battlefield environment. The ATB hardware consists of two ruggedized MicroVAX central processing units (CPUs). One CPU will be dedicated to terrain applications while the other is dedicated to weather applications (Figures 1 and 2). Both units use multiple hard disks, tape drives, graphic and alphanumeric input and output devices, and communication devices. The Terrain CPU will include an X/Y Digitizing input device and a CCD Mapping Camera. The Weather CPU will include an environmental sensor suite to detect surface and upper air meteorological data. Both CPUs will communicate with each other and with other related computer systems.

In addition to the GIS and TDA software, the ATB will consist of: operating system software (Virtual Memory System - MicroVMS), Data Base Management System (DBMS) software, GKS graphics libraries and, user interface software. These components of the ATB system software architecture will be integrated into a cohesive software package in which TDA software exploitation of terrain and weather data can occur. The ATB software will also contain language compilers for FORTRAN 77, PASCAL, C, and ADA. Figure 3 illustrates the software architecture.

The ATB will be installed into an Integrated Command Post (ICP) type shelters which are being mounted on Commercial Utility Cargo Vehicles (CUCVs) for transport during the ALBE demonstrations and evaluations. This configuration will be accomplished in October 1987.

Acquisition and integration of the ATB hardware and implementation of the system software is being accomplished under contract by Battelle Pacific Northwest Laboratories (PNL).

GEOGRAPHIC INFORMATION SYSTEM (GIS)

OVERVIEW

The ALBE Geographic Information System (GIS) consists of several software packages which enable an analyst to create, extract, store, manipulate, and display digital terrain data. This data, which can be displayed in hard and soft copy and raster and vector forms, is the basis for the production of Tactical Decision Aids.

The ALBE GIS consists of the following public domain software; the Analytical Mapping System (AMS) which allows for the digitization of data, the Map Overlay Statistical System (MOSS) which offers statistical analysis of vector data, and the Map

Analysis and Processing Subsystem (MAPS) which allows for the conversion of vector to raster data and the subsequent statistical analysis. In addition to the aforementioned basic software, the GIS includes a map projection package which allows the user to select from twenty unique map projections.

AMS, MOSS, and MAPS have been in use with a variety of computers and operating systems and as a result there is widespread knowledge, throughout the geographic information system's community, of their capabilities. This paper will not be focused on those capabilities, but will elaborate on the exploitation of those capabilities for the TDA development and enhancements to the system which are unique to the ALBE GIS.

Significant developments to AMS, MOSS, and MAPS include: the conversion from the HP-UNIX environment to a 32-bit word, MicroVMS environment, the replacement of DI-3000 with Battelle's Passthrough routines (GKS calls and Rastertek 1/10 driver), and the remodelling of the database directory structure (Figure 4). This work was performed by DBA Systems, Inc. DBA is also nearing completion on several software modules that will be integrated into the GIS. These enhancements include; Arcnode Overlay processing capability in AMS, Raster to Vector conversion, and Standard Linear Format (SLF) import and export capabilities. The Cartographic Output System (COS) is scheduled to be converted to operate with the ALBE GIS within a year. COS will enhance the system by providing cartographic quality output.

Analytical Mapping System (AMS)

Figure 5 illustrates the flow of data processing through the various software modules of the GIS. The AMS is a software package that permits the user to create a digital, geographic database. Features of AMS include: graphic display, editing, softcopy, data/integrity verification, database storage and retrieval, simultaneous user procedures, and twenty standard map projections. The AMS software is menu driven, with several layers of menus which allow the user to select options that will exploit the capabilities. AMS contains a photogrammetric subsystem which supports data extraction from various imagery sources and has been used in some ETL programs; however, there are no plans at this time to integrate this software for use in the ALBE GIS.

Once user accounts, a project area, and themes (soils, vegetation, slope, etc.) have been established, the digital database can be created. The source of data for the digital databases has been Defense Mapping Agency TTADB's (1:50000). The ALBE GIS uses an in-house attribute coding scheme to represent the features that are digitized from these TTADB's. At this point, the data exists in binary, AMS format. As a digitizing job is in process, the data is kept in arc-node format, vectors

and the attributes associated with them are stored in the system. Once the job is databased, this arc-node information is retained, as well as polygon information. AMS maintains a list of polygons and the vectors and attributes that compose them. If a segment is shared by two polygons, the coordinates for that common segment are stored once, with each polygon having a pointer to that stored segment.

Alternative data sources will be available when the Standard Linear Format (SLF) Import/Export routines are integrated into the GIS. Data created in AMS on any other computer system can be transferred to the ALBE GIS via SLF and all attributes will be directly transferred. The DMA digital data standard is in a state of transition. 2-D SLF data (TAPS FECAT coding), 3-D SLF data (DMAFF coding), and MINITOPO data (FACS coding) is or will be available. ALBE GIS will continue to use the in-house attribute coding scheme, with plans to develop conversion programs for 2-D SLF to 3-D SLF to MINITOPO formats as needed.

The existing method for complexing maps or overlaying themes in MOSS is lengthy and is not user friendly. The installation of the Arcnode Overlay Processing module in AMS will allow the user to select from a menu of complexing options. These options include forming unions, intersections, or differences of data sets. The majority of the Arcnode Overlay software is written in C, with the remainder in FORTRAN.

The user exports the data through ADDWAMS by selecting an option from an AMS menu. The ADDWAMS module allows the user to select a map projection, converts the data to ASCII and prepares it to be added to the MOSS database. The data is stored in polygon form, with common vectors duplicated.

Map Overlay Statistical System (MOSS)

MOSS is a command driven analysis and display system for map and other geo-based information and is designed to allow users to retrieve, analyze, and display maps and spatial data stored in the system. ADDWAMS data is added to the MOSS database by selecting the ADD option from the MOSSUTILITY menu. The data then exists in binary, MOSS format and is represented in vector form. Processing capabilities of MOSS commands can be broken into three groups:

MOSS - program control, and map data storage and description
MOSSANALYSIS - extraction and production of information from existing map data, usually resulting in a new map
MOSSUTILITY - general housekeeping and display of map files

MOSS data is stored in binary, MOSS format. Polygon information is preserved, with duplicate storage of shared segments.

Map Analysis and Processing Subsystem (MAPS)

Copies of the MOSS data files are generated in the MAPS database by executing the MOSSTOMAPS command. A header file, which is used to recognize the data files existing in the MAPS database is also created at this time. The RASTERIZE command can then be used to rasterize these MOSS files. Once the data has been rasterized, it exists in binary MAPS format. Polygons and segments are not preserved in MAPS. The MAPS format represents a geographic area as a grid of pixel values, with each attribute assigned a unique number. MAPS contains processing capabilities in groups similar to those of MOSS: program control, data storage, data display, and data analysis.

MAPS data, as well as other forms of raster data, can be processed further by the Raster to Vector conversion module. The user will be able to display raster data in vector form via the conversion. Data from image processing sources can be vectorized with this software, and vector and raster data sets can be converted to the same form for merging. This enhancement will also be designed to close the loop on the GIS data processing. In this way, raster data from outside sources could be brought into the ALBE GIS system, assigned attributes, and processed for use in TDA production. Three types of raster to vector conversion will exist: creating polygons or areas (soils, slope), linear features (lines, roads), and contours (elevations, moisture gradient). ICARAS, a FORTRAN package created by the EROS data center, will be used for the creation of polygons. A FORTRAN package created by BATTELLE will be used for the creation of vector contours. DBA will design the software for creating the linear features, as well as integrating the aforementioned packages into the system. Any additional software such as utility programs or libraries will be written in C.

TACTICAL DECISION AIDS

The ALBE Tactical Decision Aids are software products which predict the effects of environment on both friendly and threat materiel, weapon systems, personnel and operations. The TDA's are not intended to render decisions, but rather to supplement the tactician's knowledge base and augment the decision making process by providing information useful in the formulation and execution of battlefield strategies. The inputs to generate these products consists of Digital Terrain Elevation Data (DTED), digitized (at Army labs) Tactical Terrain Analysis Data Base (TTADB) terrain feature data, historical climatological data, near-real-time meteorological data, and miscellaneous information such as vehicle and bridge parameter lists, data on military equipment, personnel, etc. The Defense Mapping Agency has agreed to produce DTD (digitized terrain feature data) as part of their Mark 90 program in response to a request by the Army for higher resolution data. The DTD data will serve as the terrain data base for the ATB and other Army advanced technology systems.

ALBE TDA's cover the effects of both the current and forecast state of the environment. They enable the tactical commander and his staff to evaluate weapon system effectiveness, determine the advantage of one system over another, and anticipate how operations will be degraded or improved during threat/U.S. engagements. The TDAs will enhance the ability to plan and execute operations in a dynamic tactical situation, and let commanders and their staff use weather and terrain as force multipliers in employing combat assets.

There are six ALBE Tactical Decision Aid categories. They are:

- Army Aviation**
- Countermobility**
- Ground Mobility**
- Nuclear, Biological, Chemical (NBC)**
- Terrain and Atmospheric Utilities (TAU)**
- Weapon System Performance**

Each TDA category contains a number of modules; and each module produces one or more TDA products. The products of some modules can serve as input for those of another category. TDA products generated through these processes will not merely reflect the effects of any single factor, such as terrain, weather or battle-induced conditions, but rather the combined synergistic effects of a number of factors.

ARMY AVIATION

The Army Aviation TDAs will demonstrate the application of terrain and atmospheric models in analysis of aircraft performance as it contributes to the success or failure of an aviation mission. The TDA software generates both graphic plots and textual reports as output. The category consists of three modules;

- Flight Weather**
- Aircraft Vectoring**
- Aircraft Performance**

The Flight Weather module generates information on weather hazards to helicopter flight. Five interactive models allow the user to analyze different scenarios. Aircraft Vectoring allows the tactician to assess, predict and plan various aircraft operations. Ten interactive models allow the user to generate data that describes the current status of selected aircraft instrumentation and analyze the potential impact of environmental and terrain conditions. Aircraft Performance generates graphical displays and map overlays of density/altitude information for flight planning purposes. The input, either current or forecast meteorological data, is used to determine the areas where aircraft performance may be marginal or hazardous.

COUNTERMOBILITY

The Countermobility TDA's will make predictions of obstacle deployment and effectiveness considering the environment, troop and equipment assets, constraints on equipment operation and time required. Obstacles addressed include: minefields, wire, craters, rubble, ditches, log obstacles, and flood zones. The products generated allow the evaluation of alternative plans and reduce the time required to implement an integrated obstacle system. The category consists of three modules;

**Minefield Deployment Effectiveness
Obstacle Deployments
Obstacle Systems**

Minefield Deployments predicts the effectiveness and uses data from environmental sensors located in the area of interest to make real time predictions. This software allows the tactician to generate map overlays illustrating deployment performance, effectiveness, sitings, and resource requirements. Site selection products are generated using mobility, gap crossing and Line of Sight predictions which are products of other TDAs. A supporting model that addresses the impact of snow cover or frozen soil on the effectiveness of a minefield will also be implemented.

Obstacle Deployment software allows the tactician to generate a product(s) which predicts the effectiveness, location and logistics of obstacles other than minefields. Obstacle System software allows the tactician to generate overlays which show location, estimated threat force breaching times, movement restriction, time delay effectiveness and logistics. Obstacle System predictions will be available for winter conditions; ice, snow and frozen surfaces. The capability provided will enable the commander to plan tactical countermobility operations efficiently.

Ground Mobility

The Ground Mobility TDA software generates a comprehensive description of the ability of vehicles and vehicle convoys to transport men and material over virtually any type of terrain, on or off road, under nearly any weather conditions. Battlefield environmental conditions are described either on a projected or on a near real time bases. This will allow the tactician to use the products in either pre-battle planning or in battle decision making. The category consists of eight modules:

**Off Road Speed
On Road Speed
Bridge Evaluation
Gap Crossing
Formation Movement**

**Route Cover and Concealment
Integrated Mobility
Road Usage**

The Off Road Speed module is designed to predict the "GO/NOGO" and maximum speed performance of vehicles off the road considering the degrading effects of terrain and environmental conditions. Predictions can be adjusted to either agree with long term weather forecasts or reflect near real time weather. The tactician can generate map overlays including depiction of the ground vehicle "GO/NOGO" speeds, and speed performance both on an areal and a route selection basis, comparisons of off road speed capabilities of different vehicles, and reasons for vehicle off road speed reductions and NOGOS. On Road Speed module products consider vehicles operating on undamaged segments of a road and provides similar capabilities as those for Off-Road module products.

Bridge Evaluation identifies the location and characteristics of fixed bridge sites and indicates the suitability of a site for tactical bridge deployment. Gap Crossing evaluates vehicle geometry and traction performance capability relative to gap characteristics and predicts the ability to cross at selected sites. It includes a supporting model: Winter Bridging, used to locate tactical bridging sites in cold weather environments.

Formation Movement software is interactive and is designed to aid in the logistic problem of relocating manpower and resources. Route Cover and Concealment software predicts the capability of vehicles to travel on the battlefield with minimum exposure time. The resulting products can be used in combination with others to plan routes that minimize risk. Integrated Mobility is a combination of all the previously described modules. It can predict speed and/or travel time for vehicle movement either on road, off road, or across gaps; and it can generate route selection maps interactively. Road Usage software predicts the influence of road usage (vehicle speeds, traffic volume, movement times) on road damage and repair. A supporting model; Resource Planning, incorporates Ground Mobility TDA applications into the Engineer Command and Control System (ECCS) for mission planning.

Nuclear, Biological, Chemical

The Nuclear, Biological, Chemical (NBC) software generates products which provide information on the location, extent and persistence of NBC hazards and smoke; the side effects of chemical protective clothing; and options for decontamination. The category consists of four modules:

**NBC Hazard
Smoke Generation
Tube Delivered Smoke
Chemical Decontamination**

NBC Hazard automates reporting operations and provides the capability to display two and three dimensional nuclear fallout and chemical hazard areas on digital terrain map backgrounds. Smoke Generation automates the design of large area oil fog smoke screens to provide concealment and deception and to prevent operational use of various electro-optical systems. Tube Delivered Smoke uses munitions delivered by howitzers and mortars for the same purposes as Smoke Generation products. Chemical Decontamination provides the guidelines for NBC decontamination on the winter battlefield identifying, interactively, practical options for different types of equipment.

Terrain and Atmospheric Utilities

The Terrain and Atmospheric Utilities (TAU) software provides general supporting utilities which can generate stand alone products or feed data into other TDA software. The tactician can use this software to generate either graphic or textual reports of terrain and weather effects on varying military operations. The category consists of seven modules:

- Intervisibility**
- Sensor Communication and Data Handling**
- Weather Effects Messages**
- Surface and Upper Air Data**
- Military Hydrology (MILHY)**
- Target Area Winds**
- 3D Perspective View**

Intervisibility software is interactive and allows the tactician to generate eight distinct terrain based products which predict the impact of line of sight (linear and radial) on mobile and aerial military operations. The Sensor Communication and Data Handling software is ATB system level software which allows for the input of environmental data from any meteorological sensor and makes it useful for the TDAs. The Weather Effects software allows the tactician to either scan the environmental data base for parameters in excess of pre-determined critical values and warn of the potential weather impact or allows the tactician to simulate a scenario with a given set of climate/terrain values in order to determine critical considerations and effects to a number of operations.

Surface and Upper Air Data software integrates diverse environmental measurements into a coherent depiction of the current status of the weather aloft and at the surface. This software also allows the tactician to generate contour map overlays of specified met parameters in the area of interest. These products chiefly serve the interest of the Staff Weather Officer (SWO) personnel.

Military Hydrology software allows the tactician to predict forecast of water stage and flow characteristics for selected

times and cross sections within an area based on the physical watershed characteristics and the precipitation as measured by ground sensors. Target Area Winds software provides an accurate estimate of terrain influenced surface and upper level winds in target areas, ahead of the Forward Line of Own Troops (FLOT) and in other data-silent areas. Knowledge of terrain influenced wind fields will produce more accurate chemical hazard and smoke screen predictions, and will aid in the proper placement of chemical alarm sensors and billeting of troops. The 3D Perspective View software allows the tactician to generate a shaded relief terrain perspective view product which can be used as a stand alone product to provide the commander with a realistic window to view the battlefield environment or as a background map onto which could be draped a time/event sequenced chemical or smoke generation product. The latter example would depict the influence of the terrain and wind field as the cloud plume disperses throughout the area of interest.

Weapon System Performance

The Weapon System Performance software considers the impact of environmental effects on the effectiveness of electro-optical and seismic/acoustic sensors and systems. The tactician can use the software to generate information for friendly and threat conditions, currently fielded and developmental imagers, lasers, and guidance devices such as used on the TOW; self contained munitions such as SADARM; advanced munitions such as FOG-M and AAWS-M; and aided target recognition (ATR) devices. The category consists of four modules:

Electro-Optical Systems

Top Attack Self Contained Munition (SCM) Systems

Seismic/Acoustic Sensor Systems

Advanced Munitions

The output for Electro-Optical Systems will consist of tables depicting the effective ranges of devices used for target acquisition and map overlays displaying line of sight limitations on the terrain. Top Attack SCM system software will predict the performance of different target types, sensor logic and sensor scan characteristics and it will determine optimum terrain deployment sites for SCM/target engagements. Seismic/Acoustic Sensor Systems will provide techniques to detect, locate, and classify threat vehicles. Advanced Munitions will predict the performance of automatic target recognition devices in current of forecast environmental conditions.

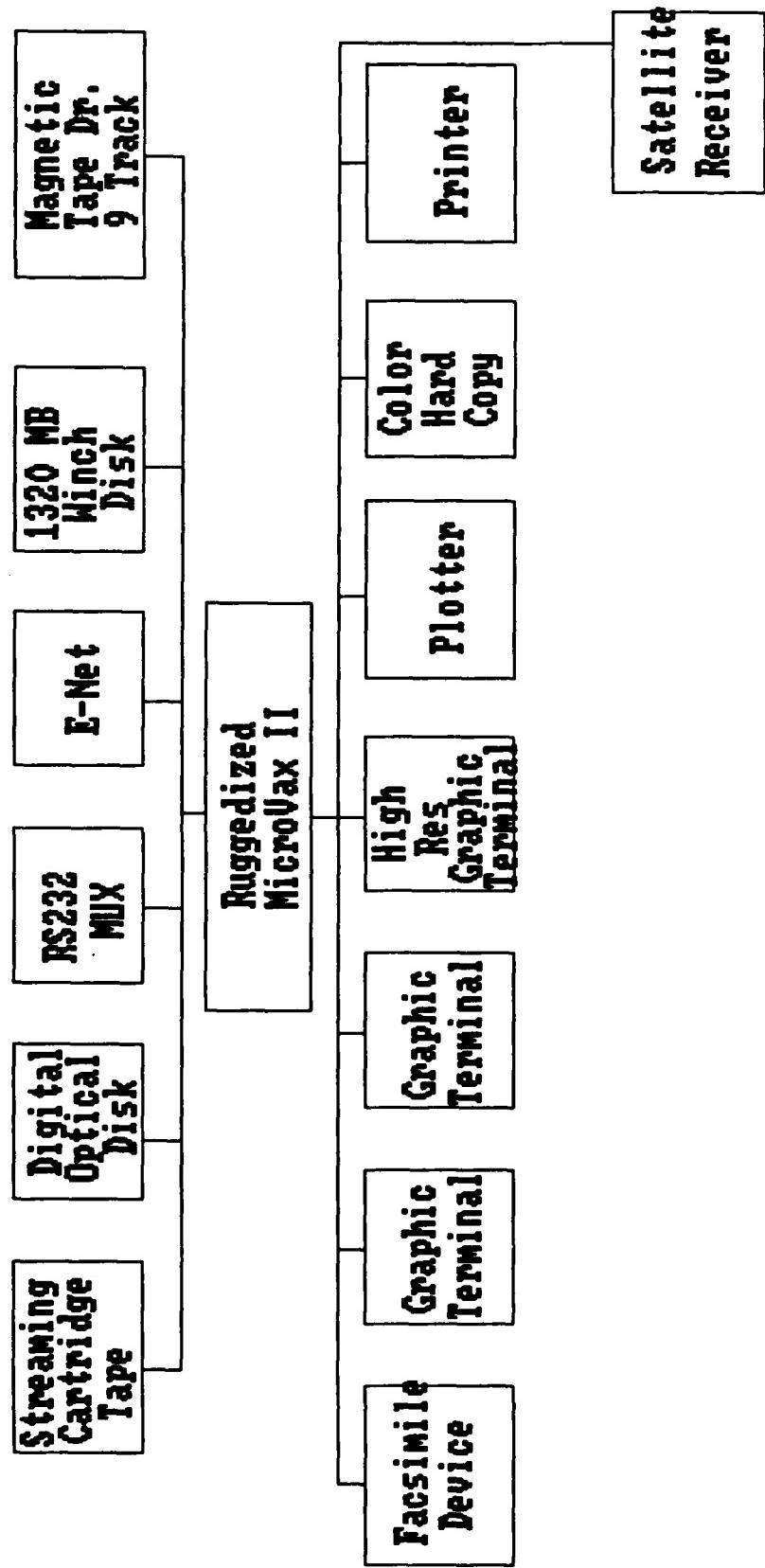


FIGURE 1:
Block Diagram of the Heather-Intensive AT&T Processor

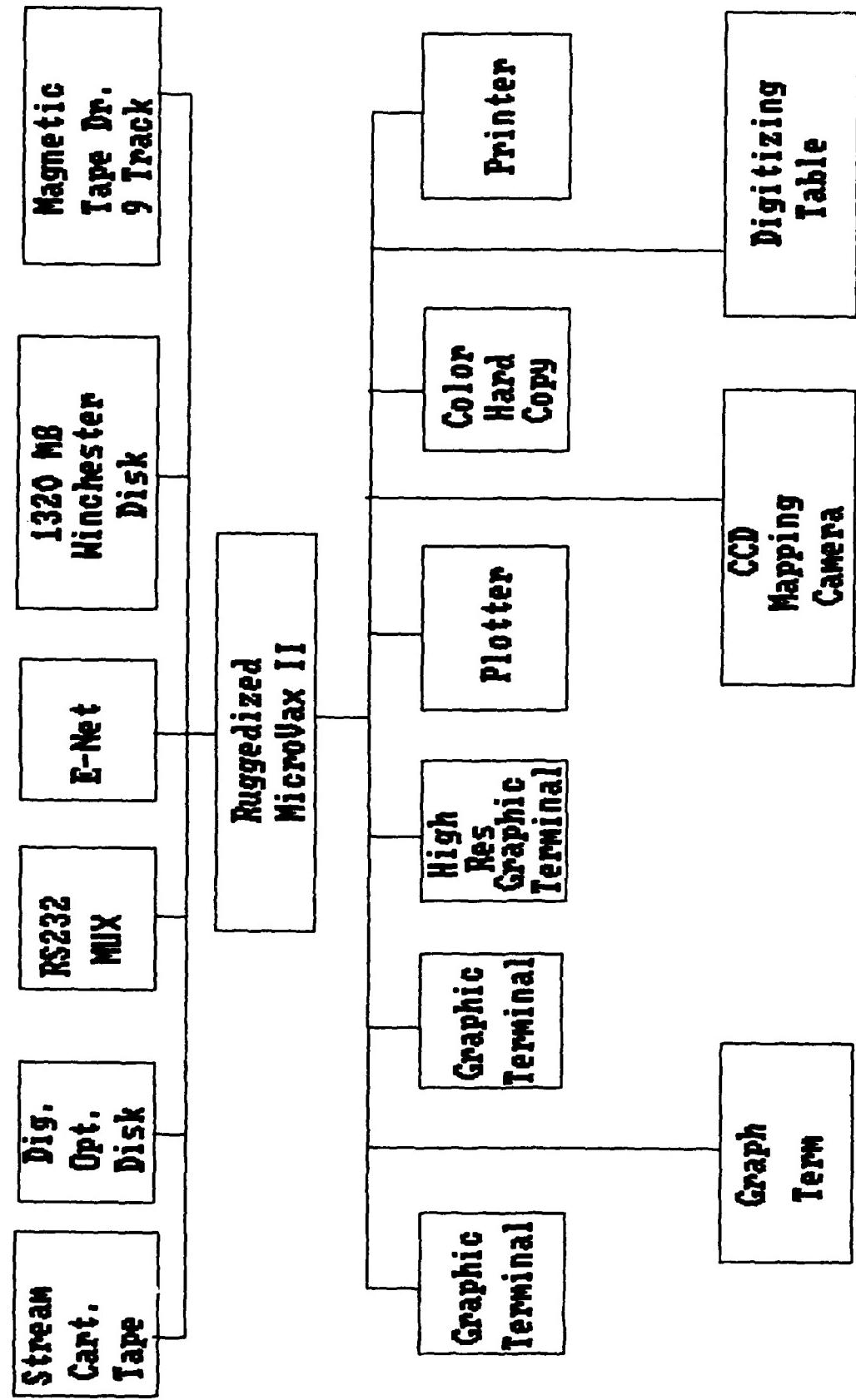


FIGURE 2:
Block Diagram of the Terrain Intensive ATS Processor

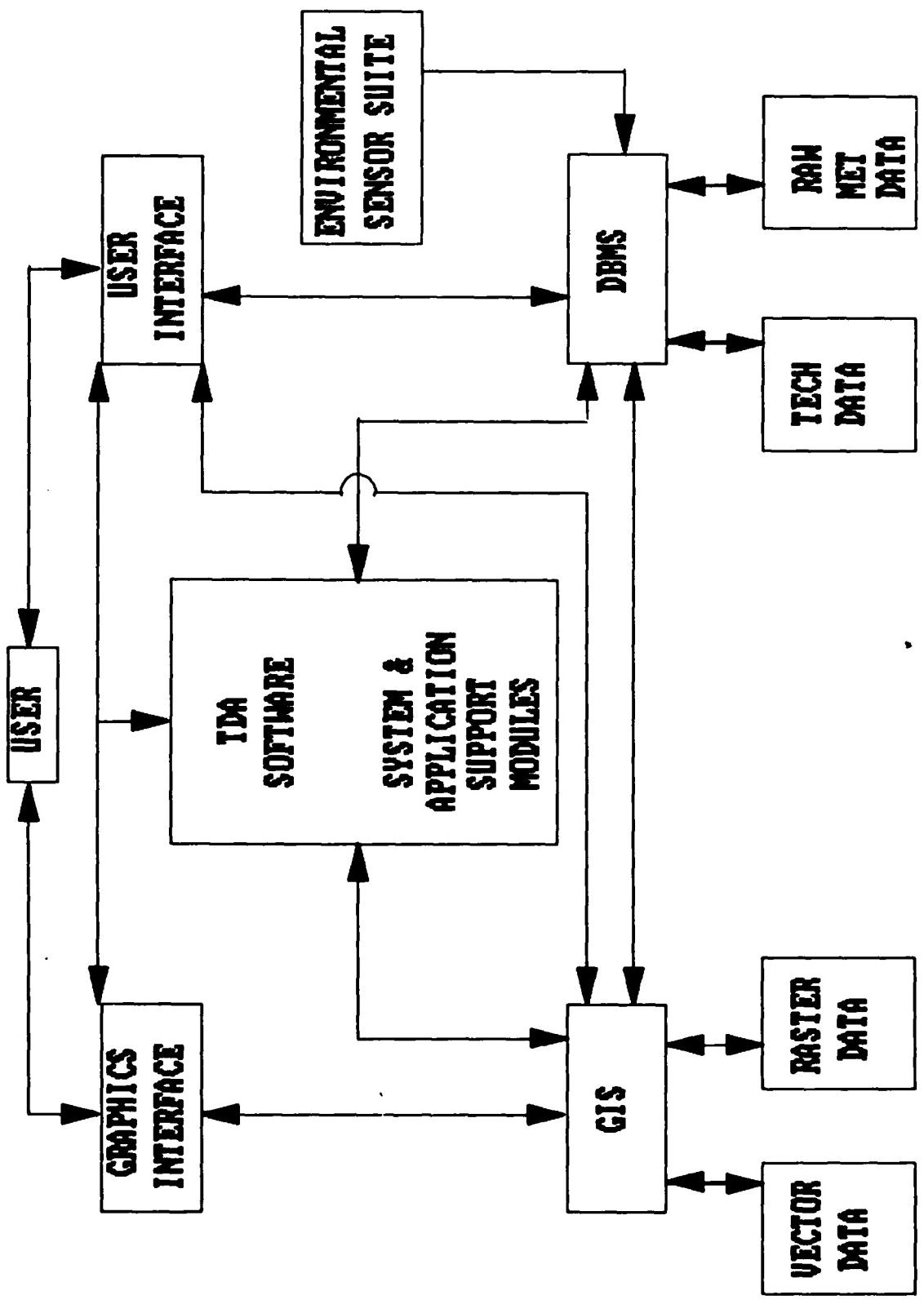


FIGURE 3: ALBE SYSTEM SOFTWARE ARCHITECTURE

ALBE GIS DATABASE DIRECTORY STRUCTURE

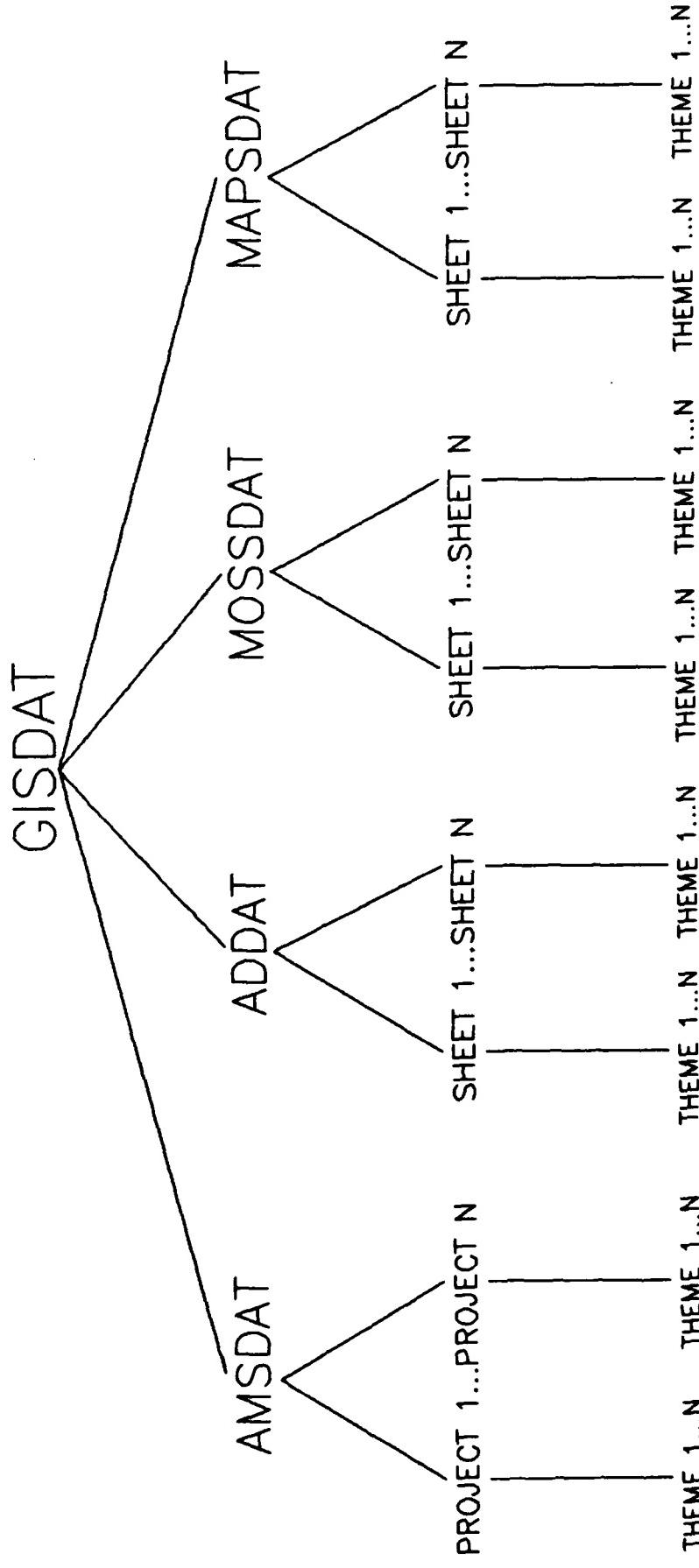


Figure 4

Flow of the ALBE GIS Data Processing

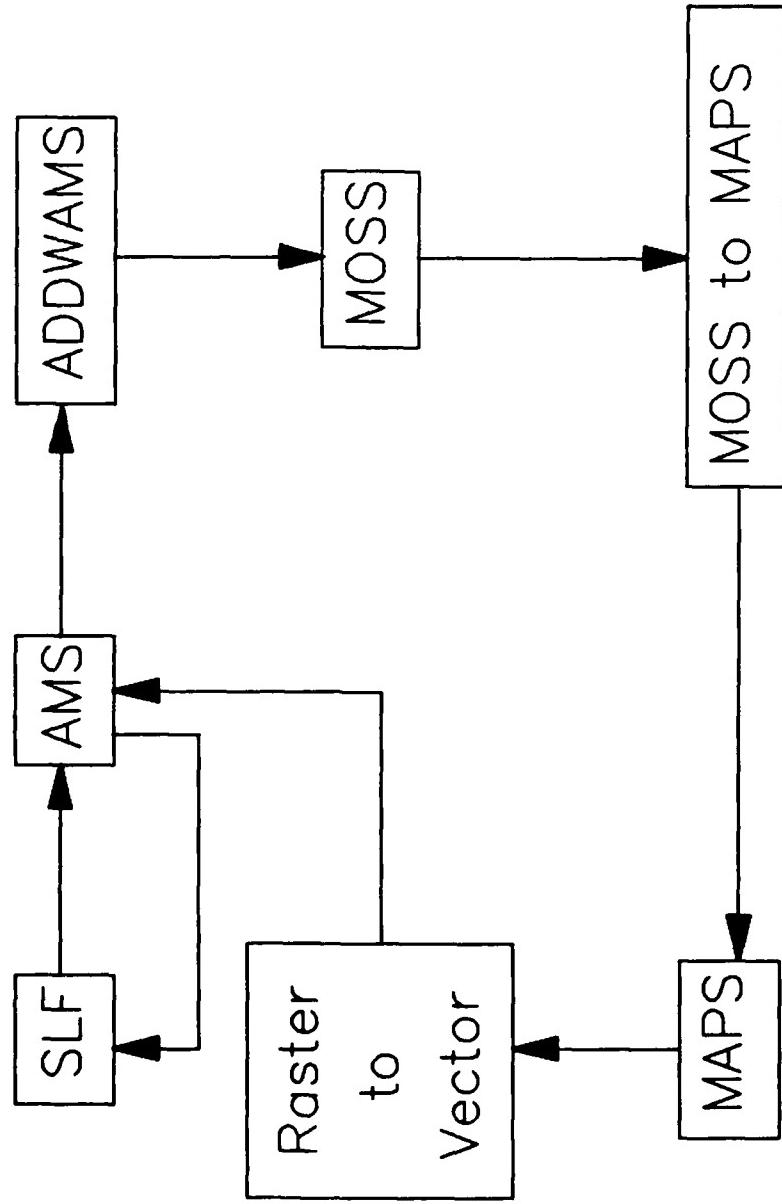


Figure 5

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